rocks have been subject to very considerable mass-movements and deformation, the displacements amounting in extreme cases to as much as ten miles in the vertical and one hundred miles in the horizontal direction. The ultimate cause of these movements is unknown; they can only be directly observed in the outermost skin, and are probably taken up in a different form in the deeper layers, but require that beneath the outer solid layer—which for convenience, and because some name is required, is commonly called the crust—there must be material which has some of the properties of a fluid, but not necessarily more than the power of change of form when exposed to stress of sufficient magnitude and duration. The thickness of the outer crust has been estimated by several distinct lines of deduction, all of which agree in giving a figure of about twenty-five miles, and this may be taken as indicating the order of its magnitude. The only means of arriving at any idea of the nature of the transition from the crust to the underlying material is in the reflection of earthquake waves; this is ordinarily treated as taking place at the surface of the earth, but there are grave difficulties in the way of accepting this interpretation. A more probable one is that reflection takes place at the under-surface of the crust, indicating a somewhat abrupt transition from the solid and rigid crust to the more yielding layer below. Whether this is a separate layer or merely the outermost part of the shell capable of transmitting both forms of elastic waves is still unknown.

The general result is that three distinct divisions can be recognised in the interior of the earth:—(1) The outer crust of solid matter possessing a high degree of rigidity, whether against permanent or temporary stress, of comparatively small thickness amounting to about ½ per cent., and not more than 1 per cent., of the radius; (2) a shell of material of thickness about one-half of the radius which has a high rigidity as against stress of the duration involved in the production of the tides, or of shorter duration, but, in the outer part at least, a comparatively low power of resistance to stress of secular duration; and (3) a central nucleus of material which has a very low degree of rigidity, even against stress of only a few seconds' duration. The transition from the first to the second of these three divisions is somewhat abrupt, sufficiently so to give rise to reflection; between the second and third the passage is more gradual, and lies at about four-tenths or five-tenths of the radius from the centre of the earth. These three divisions may be further reduced to two—the outer layer, which in geology is known as the crust, not from any implication of the nature of the rest of the earth, but merely in recognition of a difference in character; and the central core, consisting of the rest of the earth.

HYDRO-ELECTRIC POWER SUPPLY.[1]

LARGE works have been established for supplying Bombay with water-power for its numerous mills and factories, which have hitherto used steam-power, to the extent of more than 100,000 h.p. Coal in most of India is too expensive to allow competition with other countries for many products, though the raw materials are grown or found in India, and labour is cheap and docile, while highly educated Indians abound. To Bombay coal has mostly to be carried about 1200 miles.

The water-power now provided is very much cheaper than power from coal or oil, gives a better "drive," and frees Bombay from the clouds of deleterious smoke which the poor Indian coal gives.

The works take advantage of the very heavy rainfall on the precipitous edge of the Western Ghats, about 2000 ft. above, and about forty miles from, Bombay. As the rain falls only during three or four months of the year and the watercourses are dry all the rest of the year, it was necessary to store water sufficient to give about 100,000 h.p. for ten or twelve hours a day during about nine months of the year.

Three lakes are formed by four masonry dams, ranging from nearly ¾ mile long and 34½ ft. high to nearly 1½ miles long and 96 ft. high. Two of these form a "monsoon" lake of sufficient capacity to provide power during the longest "breaks" in the monsoon, and thus give an uninterrupted supply of power for three months and more. The other lakes are for storage, and maintain the power during the eight or nine months in the year when no rain falls.

The monsoon rain on the Western Ghats, though always heavy, is very variable in amount. The least annual amount during the last forty-eight years was 82 in. on the edge of the Deccan plain, and the greatest amount during the past eleven years, in which special gauges have been fixed, on hilltops as well as in plains, is 546 in., which fell in a little more than three months, 460 in. falling in about two months. The minimum fall of 82 in. is very exceptional, and the maximum given may be equally so. The combined available capacities of the two storage lakes is about 10,100,000,000 cubic ft., whilst the water required to give 100,000 h.p. ex turbines for nine months, allowing for the great loss by evaporation and by soakage and for friction in the pipes and turbines, is 6,700,000,000 cubic ft. The excess capacity is given owing to the very variable amounts of the monsoon rains, so as to carry on the balances in years of excessive rainfall to make up for the occasional short monsoons. It was arrived at by assuming the works had been completed forty years ago, there being one rain-gauge record covering that period—which includes four minimum years' fall—and deducting from each year's supply the amount which would have been used, lost by evaporation, run to waste, or carried on to the next year, which gives the excess capacity required for a sufficient number of years.

The amount of 546 in. measured at one hill station in the lakes catchment is not more than has been measured in two or three out of the past fifty odd years at Cherrapunji, in the Assam Hills, which has the heaviest rainfall hitherto known; but there rain falls during seven months of the year, so that the amount measured for this work for that particular year may claim to be the heaviest rainfall ever yet measured.

The works are notable for the following reasons:—They are the largest of the many similar hydro-electric works which have been constructed during the past ten or twenty years, taking into consideration the great head used, combined with the large discharge of water. The first is equal to about five times the height of St. Paul's Cross, and the latter is greater than the summer flow of the River Thames during five months. They are also the first works to store water for power for use during about three-fourths of the year. One of the masonry dams, taking the exposed face area, is probably the largest yet constructed. The works are probably unique, considering the very heavy rainfall and the very steep rocky slopes, giving the greatest discharge perhaps ever recorded. The catchment area of the two lakes is only 16½ square miles, while of this the full lakes area is about 7½ square miles.

The water is led from the monsoon lake and from

---

[1] Abstract of a paper on "The Tata Hydro-electric Power-supply Works, Bombay," by Mr. R. B. Joyner, read at the Institution of Civil Engineers on November 19.

© 1918 Nature Publishing Group

the two storage lakes, which are joined together by a tunnel a mile long, by two ducts, together 4·63 miles long, to the forebay at the top of the great precipitous scarp which forms the western boundary of the Deccan plateau. From there the two lines of steel pipes are taken down the steep slopes and precipices to the power-house, about 1750 ft. below the forebay, the length of single line being about 2·33 miles. The pipes at the top are 82½ in. in internal diameter, and at about two-thirds of the total height down the diameter is 72 in. Here they are joined by a double swan-neck pipe, from which eight smaller pipes are led down to the power-house, their diameter being 3½ ft. at the top, and 3 ft. 2 in. at the bottom. The thickness of the metal at the top of the large pipes is ⅝ in., and at the bottom of the small pipes 1¼ in.

Each of the lower smaller eight pipes supplies a Pelton-wheel turbine, designed to give a maximum of 13,500 h.p. with automatic regulation devices.

The works described are the first to be undertaken of a number of similar works proposed by the author, he having shown that it is financially possible in India to store water for use during eight or nine months of the year, and give power at a much cheaper cost than by the use of coal, oil, or spirit from vegetable products; likewise cheaper than power from the wind, sun, or tides. Not only that, but the water after use is available for irrigation, so valuable in a country without a drop of rain for a large part of the year. This would ensure the growth of the raw materials required for finished products on which the country is now so dependent upon other countries. It would also supply the factory workers or others with food and drink, and help to prevent famines, besides doing much to regularise the rainfall. Such power will provide electric traction for raw materials to, and finished products from, the factories, as well as light for them and neighbouring towns, produce fertilisers, and give the great heat required for the smelting of ores. Many industries would then be self-contained, and India could compete with Europe, America, or Japan for its finished products, and would become less dependent upon its agriculture, which the varying seasons render somewhat capricious.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

EDINBURGH.—The University, which as yet has no professor of geography and only one lecturer on the subject, as compared with three professors and five lecturers in branches of history, has recently so far recognised its growing importance as to institute a diploma in geography, based on regulations involving a thorough and far-reaching study of certain aspects of geographical science. The diploma is intended for graduates in arts or science prepared to devote an additional *annus academicus* to the subject, and capable of passing an examination of somewhat high standard. The limited number of courses in pure geography available in the University under present conditions has made it necessary to have recourse extensively to other departments, and the aim of the regulations appears to be to induce students to specialise either in historical and economic geography or, but less markedly, in mathematical geography. A special feature is the stress laid upon economic ethnography, defined as the study of the influence of geographical environment on the life of the most important peoples. The regulations give much less scope to graduates whose tastes lie in the direction of physical geography in the wide sense, and, in view of the contributions which Scotland has made to oceanography and meteorology, it is remarkable that neither of these subjects finds a place in the list. Further, geology, which, especially in its physical aspects, has always had so many adherents in Scotland, is represented only by one optional course, and, like general geography, does not appear among the subjects of the diploma examination; nor does any branch of biology find a place there. Should it be found possible later to enlarge the department by the addition of new lecturers, the present diploma might fittingly become one in economic geography.

THE Aitchison memorial scholarship, founded in memory of the late Mr. James Aitchison, and tenable at the Northampton Polytechnic Institute for two years, 1918–20, has been awarded to Mr. V. C. Milligen, Goodmayes, Essex.

WE learn from the *Times* that the council of Clifton College has just received the sum of 1000*l.* from an old Cliftonian, Mr. W. J. Leonard, for the establishment of a leaving scholarship to Oxford and Cambridge in chemistry, physics, or biology, in memory of the mastership at Clifton of Mr. T. W. Dunn, assistant master and house master at Clifton from 1868 to 1878. While the scholarship is to be given to enable boys of good promise to pursue the study of natural science at the old Universities, it is only to be awarded to a candidate who has been in the sixth, or at least the fifth, form on the classical side.

THE Labour Party at its meeting on November 14 at the Royal Albert Hall to open the election campaign of the party adopted the programme drawn up by its executive committee. Of the twenty demands contained in the manifesto one deals with education, and runs as follows:—"A national system of education, free and effectively open to all persons, irrespective of their means, from the nursery school to the university; based on the principle of extending to persons of all ages, without distinction of class or wealth and without any taint of militarism, genuine opportunities for the most effective education on a broad and liberal basis, and the provision for teachers of all kinds and grades of salaries, pensions, training, and opportunities of advancement commensurate with the high social importance of their calling." No exception can be taken to the reasonableness of the ideals inspiring this statement, but it must be borne in mind frankly that not every boy and girl can benefit from a course of higher education, and that all that it is wise to insist upon is that every child shall have the opportunity of developing his intellectual powers to their fullest extent, and that social distinctions shall not be a bar to merited educational advancement.

A REPORT on the work of the Manchester Municipal College of Technology for the years 1913 to 1918 has just been published. The issue of annual reports was interrupted in 1914. The college has made its principal contribution to the task of winning the war by supplying the Army and Navy with men whose character and intelligence owe a great deal to their university training. It has supplied to the Royal Engineers, as well as to the technical branches of the Navy, Army, and Air Force, men whose training as engineers, chemists, or other technologists has enabled them to render effective service. In addition to supplying men, the college has undertaken war-work of different kinds. So great, indeed, have these new activities been that, despite the large reduction in the number of students, more research work has been done in the college during the past four years than in any other equal period of its history. The buildings and equipment have been improved in various ways during the period under review. In the

© 1918 Nature Publishing Group